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I, JULIE BILLINGSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2002953559 for a patent by SEAPOWER PTY LTD as filed on 23 December 2002.

I further certify that the above application is now proceeding in the name of SEAPOWER PACIFIC PTY LTD pursuant to the provisions of Section 113 of the Patents Act 1990.

COMMONWEALTH OF AUSTRALIA
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WITNESS my hand this
Seventh day of July 2003

J. Billingsley

JULIE BILLINGSLEY
TEAM LEADER EXAMINATION
SUPPORT AND SALES

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ORIGINAL

AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

Invention Title: Apparatus for Capturing Wave Energy

The invention is described in the following statement:

"Apparatus for Capturing Wave Energy"

Field of the Invention

This invention relates to the capture of wave energy from a body of water.

The invention has been devised particularly, although not necessarily solely, for harnessing ocean wave energy and converting the harnessed energy to pressurised seawater for use in any appropriate way. For example, the seawater under high pressure may be is piped ashore as a motive fluid to drive turbines for onshore electricity generation. The high-pressure water may also be used directly for desalination via the reverse osmosis process without the need for auxiliary energy input for pressurization.

Background Art

There have been many proposals for devices that seek to harness ocean wave energy but only a few of such devices are actually under sustained commercial development. All of the commercial devices, whether shore based, ashore or offshore, have their energy conversion to electricity with the necessary equipment located *in situ*. This means the critical components such as turbines, alternator/generators and electrical distribution infrastructure must be able to withstand the marine environment including such factors as: the force of storms, prolonged exposure to seawater, and accidental immersion in seawater. In the case of offshore devices, there is also the need for extensive undersea power cabling to bring electricity to shore. The net result is increased capital cost and decreased reliability.

One of the difficulties faced in the design of a wave energy extraction system is the unfavorable tradeoff between on the one hand the need for resonant extraction which requires a structure that is large and therefore costly, and on the other hand the need to contain costs.

Many wave energy devices that have already been proposed and developed, such as floating buoys, may be considered to be 'point absorbers'; that is, they absorb energy from the wave over a scale length not greater than their physical size, which is small compared to the wave length. It has been recognised that energy absorption can be enhanced in such devices by artificially realigning the response of the device to the wave period by a process known as 'latching'. This involves some means of freezing the mechanism of the device so that it waits until the wave has caught up before activating the device to receive the energy from a wave peak. Similar latching may be done after the passage of a wave to prepare the device for favourable reception of the next wave peak. The latching means may include hydraulic, pneumatic or electromechanical means and in all cases requires an external source of energy and timing information.

While latching has been shown to be somewhat beneficial for a system that is naturally well away from (usually well above) resonance with the ocean waves, it does have significant disadvantages. Firstly, latching employs actuators that must apply a brake or lock to the main wave capture mechanism during some portion of its motion. This process fundamentally absorbs energy that could otherwise have been usefully harnessed. Moreover the braking requires equipment that can withstand the forces involved and dissipate energy quickly. Secondly, this equipment requires an external source of power that will detract from the net power output of the device. Thirdly, a means of external timing of the latching process is required, either through a feedback loop, a heuristic learning system or some other information processing means. The range of control is not sufficient to maximize the capture across the range of wave periods encountered in real sea states. A latching system adds complexity and cost to a wave energy device and with at best modest gains in net efficiency.

The present invention seeks to reduce or overcome at least some of the abovementioned difficulties associated with prior art proposals, or alternatively to provide a useful option to such prior art proposals.

Disclosure of the Invention

According to one aspect of the invention there is provided apparatus for capturing wave energy in a body of water, the apparatus comprising a body structure having a portion thereof adapted to deflect in response to wave action, a holding chamber adapted to undergo volume expansion and contraction in response to deflection of said portion, the holding chamber being in fluid communication with the body of water to receive water therefrom upon volume expansion of the holding chamber, a pumping chamber adapted to undergo expansion and contraction in response to deflection of the portion of the body structure, the pumping chamber having an inlet communicating with the holding chamber to receive water therefrom and an outlet, whereby water from the holding chamber is drawn into the pumping chamber upon volume expansion thereof and is discharged through the outlet in a pressurised condition upon volume reduction of the pumping chamber, and means for applying a selectively adjustable restoring force to said portion for biasing the holding chamber into a condition corresponding to volume expansion thereof.

With the invention, a degree of resonant energy extraction from wave action can be achieved with apparatus that is physically smaller than a half wavelength of the wave. Energy can be extracted in resonance with the wave action by virtue of the selectively adjustable restoring force.

The apparatus according to the invention provides a mechanically resonant system, making it fundamentally easier to extract energy from wave action and also to apply well-known frequency and phase shifting techniques to adapt the response of the apparatus to a range of wave periods.

The means for applying a restoring force may comprise a volume of gaseous fluid adapted to undergo compression upon volume reduction of the holding chamber. This arrangement thus provides a gas spring.

The volume of gaseous fluid may be confined in a zone comprising an upper region within the holding chamber above the volume of water contained therein. The zone may further comprise an auxiliary chamber of substantially constant volume in communication with the upper region of the holding chamber for gaseous fluid flow therebetween.

Means may be provided for supplying the zone with a charge of gaseous fluid and also for selectively varying the volume of the charge. The ability to vary the volume of the gaseous fluid charge provides a mechanism for selectively adjusting the spring force generated by the gaseous fluid as it undergoes compression.

Preferably, the gaseous fluid is air. Conveniently, the air is atmospheric air supplied by way of an air supply line extending to a location above the body of water.

Typically, the body of water is the ocean, in which case the water is seawater.

The portion of the body structure adapted to deflect in response to wave action preferably comprises a plunger exposed to the body of water incorporating wave action. The plunger may comprise a substantially rigid plate exposed to hydrodynamic forces generated by wave action.

The body structure may comprise an upper and lower portions arranged telescopically with respect to each other, with the lower portion being fixed with respect to the floor of the body of water and the upper portion being movable with respect to the lower portion in response to wave action.

The holding chamber may be defined within the upper and lower portions, and the pumping chamber may be disposed between the upper and lower portions.

The upper and lower portions may define a gap therebetween through which water from the body of water in which the apparatus is immersed can flow to enter the holding chamber as previously described.

A valve system may be associated with the inlet and outlet of the pumping chamber. Preferably, the valve system includes an inlet valve adapted to open upon volume expansion of the pumping chamber and adapted to close upon volume reduction of the pumping chamber. Preferably, the valve system further includes an outlet valve associated with the outlet, the outlet valve being adapted to close upon volume expansion of the pumping chamber and to open during volume reduction only after water contained within the pumping chamber thereof attains a prescribed pressure. In this way, water is discharged from the pumping chamber is at a higher pressure than the intake pressure.

The pumping chamber may comprise a bellows structure. One end of the bellows structure may be connected to the upper portion of the body and the other end of the bellows structure may be connected to the lower portion of the body.

Brief Description of the Drawings

The invention will be better understood by reference to the following description of several specific embodiments thereof as shown in the accompanying drawings in which:

Figure 1 is a schematic cross-sectional view of a wave energy conversion apparatus according to the first embodiment, the apparatus being illustrated in a state corresponding to the passing of a wave trough over it;

Figure 2 is a view similar to Figure 1 except that the apparatus is illustrated in a state corresponding to the passing of a wave peak over it;

Figure 3 is a cross-sectional view of the apparatus in the same state as depicted in Figure 2, with arrows indicating the direction of airflow within the apparatus;

Figure 4 is a cross sectional-view of the apparatus in the same state as depicted in Figure 1, with arrows indicating the direction of airflow within the apparatus and also the direction of seawater flow;

Figure 5 is a detailed cross-sectional view of the apparatus, illustrating in particular the disposition of vertical guiding runners, with arrows indicating the direction of seawater flow;

Figure 6 is a top view of the apparatus, illustrating in particular the angular disposition of the guiding runners;

Figure 7 is a detailed cross-sectional view of the apparatus, illustrating an air pump utilized therein;

Figure 8 is a detailed cross-sectional view, illustrating a water pump utilized therein;

Figure 9 is a detailed cross-sectional view of the apparatus, illustrating the disposition of a bellows pumping chamber and related components utilized therein, with arrows indicating the direction of seawater flow.

Figure 10 is a detailed cross-sectional view of the apparatus, illustrating a sealing means utilized therein;

Figure 11 is a detailed cross-sectional view of the apparatus, illustrating the disposition of a manifold, low pressure feed line and high pressure line, with arrows indicating the direction of seawater flow;

Figures 12 and 13 are detailed cross-sectional views of the manifold;

Figure 14 is a cross-sectional view of a wave energy conversion apparatus according to the second embodiment, the apparatus being illustrated in a state corresponding to the passing of a wave trough over it;

Figure 15 is a view similar to Figure 14 except that the apparatus is illustrated in a state corresponding to the passing of a wave peak over it;

Figure 16 and 17 are detailed cross-sectional views of apparatus of the second embodiment illustrating the disposition of a dual manifold, bellows pumping chamber, support frame and connecting strut;

Figure 18 is a detailed cross sectional view of the inner workings of the dual manifold of the apparatus of the second embodiment, with arrows indicating the direction of high pressure and low-pressure seawater flow;

Figure 19 is a close up view of one of valve elements of the dual manifold of figure 18 and, in particular, the two positions of the flap valve;

Figure 20 is a cross-sectional view of a wave energy conversion apparatus according to the third embodiment, the apparatus being illustrated in a state corresponding to the passing of a wave trough over it;

Figure 21 is a view similar to Figure 20 except that the apparatus is illustrated in a state corresponding to the passing of a wave peak over it; and

Figure 22 is a detailed cross-sectional view of apparatus according to the third embodiment, illustrating the disposition of the upper and lower support frames relative to the bellows pumping chamber and manifolds therefor.

Best Mode(s) for Carrying Out the Invention

The embodiments shown in the drawings are each directed to an apparatus for harnessing ocean wave energy and for converting the harnessed energy to high-pressure seawater. The apparatus rests on the sea floor in relatively shallow waters and creates minimal environmental impact. The high-pressure seawater is piped to shore for use in any appropriate purpose. In one application, the

high-pressure seawater may be used as a motive fluid to drive a turbine, with the shaft power therefrom being used to generate electricity. In another application the high-pressure seawater may be fed to a reverse osmosis desalination unit from which fresh water can be generated. The saltwater concentrate from the desalination unit, which is still at high pressure, may then be fed to a turbine for extraction of mechanical energy.

Referring now to Figures 1 to 13 of the drawings, the apparatus 10 according to the first embodiment comprises a body structure 11 comprising a base 13 adapted to rest on the seabed 15 and a wall structure 17 located on the base 13. The wall structure 17 includes an outer wall portion 19, an intermediate wall portion 21, and an inner wall portion 23, each of which is of generally cylindrical construction. The wall structure 17 further includes an upper web portion 25 extending between the upper ends of the outer and intermediate wall portions 19, 21, and a lower web portion 27 extending between the intermediate and inner wall portions 21, 23.

The outer wall portions 19 of the body structure 11 extend upwards from the seabed 15 to a point somewhat below the mean level of the sea. The apparatus 10 is placed in relatively shallow waters where there is a significant proportion of wave energy extending downwards from the free water surface. In this manner the apparatus creates a significant peaking of the wave energy as a wave peak passes over it and thus concentrates the energy of the water column onto the upper surface of the apparatus.

The body structure 11 further comprises a plunger 31 operating in cooperation with the wall structure 17. The top of the body structure 11 is rounded along the outer edge and also along the edge adjacent to the plunger 31.

The plunger 31 comprises a circular plate 33, and outer and inner cylindrical wall portions 35, 37 depending therefrom. The plunger outer wall portion 35 cooperates with the intermediate wall portion 21, and the plunger inner wall portion 37 cooperates with the inner wall portion 23, as will be described in more detail later.

With this arrangement, the plunger 31 defines an upper portion 41 of the body structure 11, and the base 13 and wall structure 17 define a lower portion 43 of the body structure 11. The two portions 41, 43 are arranged telescopically with respect to eachother, with the lower portion 43 fixed with respect to the seabed 15 and the upper portion 41 being moveable in response to wave action in the ocean.

With the telescopic relationship between the two portions 41, 43, the plunger outer wall 35 slides with respect to the intermediate wall portion 21, and the plunger inner wall 37slides with respect to the inner wall portion 23.

A plurality of circumferentially spaced guiding runners 45 are disposed between the plunger outer wall 45 and the intermediate wall portion 21. The guiding runners 45 maintain the concentric alignment of the plunger 31 within the apparatus 10 and also allow a relatively low friction sliding contact as the plunger 31 moves vertically in response to wave action. The guiding runners 45 are composed of a material that provides low surface friction as well as having shock absorption properties. Suitable materials may be found in the range of commercially available elastomers. The guiding runners 45 are also designed to wear without fracture, spalling, tearing or ripping. A series of slots (not shown) cut in the intermediate wall 21 form vertical recessed channels that receive and retain the guiding runners 45 to locate them in position. Periodic replacement of the guiding runners 45 may be accomplished by vertical removal of the runner from the slots. This may be accomplished from outside the apparatus 10 by attaching a lifting means to a hook (not shown) on the upper end of each runner and pulling the runner upwards until free of the apparatus. Insertion of new runners is accomplished in exactly the reverse manner.

The presence of the runners 45 establishes a gap 47 between the outer periphery of the plunger 31 and the adjacent inner wall portion 21. The size of the gap 47 is set to allow the free passage of seawater from the surrounds into the apparatus 10, as will be described later. The gap spacing is maintained by the guiding runners 45 and is set to inhibit access by humans or larger sea

creatures but to also allow passage of smaller sea creatures such as crayfish or lobsters. The gap spacing may be less than 0.5 metres and preferably less than 0.2 metres.

The apparatus 10 is not closed to the seawater since seawater can readily flow through the gap 47. This is of importance as it obviates the need for a water seal between the upper and lower portions 41, 43. Such seals are problematic in ocean environments where in situ repair would be difficult.

A fluid seal 49 is provided between the plunger inner wall 37 and the adjacent inner wall portion 23.

The upper and lower portions 41, 43 cooperate to define a holding chamber 51 which undergoes volume expansion and volume contraction in response to reciprocatory motion of the plunger 31.

An auxiliary chamber 53 is defined with the body structure 11. The auxiliary chamber 53 is disposed around and below the holding chamber 51 and communicates with the holding chamber 51 by way of apertures 55 in the plunger inner wall 37.

The holding chamber 51 is adapted to receive a volume of seawater from the body of seawater surrounding the apparatus 10 by way of the gap 47, as previously described. The volume of seawater contained in the holding chamber 51 is identified in the drawings by reference numeral 60. The volume of seawater 60 is at a level below the upper edge of the inner wall portion 23 as well as below the apertures 55. The seawater level is depicted in the drawings by a line identified by reference numeral 61.

A volume of air is confined within a zone 73 within the body structure 11. The zone 73 comprises the auxiliary chamber 53 (which is of constant volume) and the upper region within the holding chamber 51 above the volume of seawater 60. With this arrangement, the volume of air under goes compression as the holding chamber undergoes volume reduction upon downward movement of the

plunger 31 in response to wave action (or more particularly as a result of increasing hydrodynamic forces acting on the plunger plate 33). In this way, the air acts as a spring which provides a restoring force resisting downward movement of the plunger 31 and urging the plunger in the upward direction upon the subsequent reduction of the hydrodynamic forces.

The zone 73 is charged with air delivered from the atmosphere by way of an air line 75 extending upwardly from the body structure 11 to above the ocean surface, as illustrated in Figures 1 and 2. The upper end of the air line 75 is fitted with a marker 77 for identification purposes. The air line 75 is connected to an air pump 81 which is accommodated in the auxiliary chamber 53 and which is operable to pump air from the atmosphere into the zone 73, or discharge air from the zone 73 back to the atmosphere, according to the requirements of the apparatus 10 at any particular time. The air pump 81 is driven by a hydraulic motor 83 operated from a supply of pressurised seawater, as will be explained later.

The seal 49 is intended to provide protection against splashing from the holding chamber 51 that would otherwise cause a small quantity of seawater to enter the auxiliary chamber 53 and pool at the base 13 of the body structure 11. A water pump 85 is provided to remove any seawater that may gain access past the seal 49. The water pump 85 has an intake 87 and an exhaust 89 opening onto the surrounding body of seawater. The water pump 85 is driven by a hydraulic motor 91 operated form a supply of pressurised seawater, as will be explained later.

The exhaust 89 communicates directly with the surrounding seawater outside the apparatus 10. The intake 87 is located with its opening close to the base 13. In this manner the pump 85 can act as a bilge pump removing any seawater that migrates thereto. The exhaust 89 of the water pump 85 communicates with the seawater outside the apparatus via a non-return valve. The non-return valve ensures that seawater does not flow back into the apparatus due to the hydrodynamic pressure difference. A non-return valve is not required on the exhaust 92 of the hydraulic motor as the spent water that exits the motor is still at

a pressure greater than the hydrodynamic head of the surrounding seawater.

A pumping chamber 101 is disposed between the upper and lower portions 41, 43 and is adapted to undergo volume expansion and volume reduction upon reciprocatory motion of the plunger 31 in response to wave action. The pumping chamber 101 is defined by a bellows pump 103, one end of which is connected to the plunger plate 33 and the other end of which is connected to a frame structure 105 rigidly mounted on the base 13.

The pumping chamber 101 communicates with a manifold 107 having an inlet 109 and an outlet 111. The inlet 109 communicates with the holding chamber 51 by way of a feed line 113 to receive seawater therefrom. The intake end of the feed line 113 is fitted with a filter for filtering the seawater prior to delivery to the pumping chamber 101. The outlet 111 communicates with a high pressure line 117 along which seawater pressurised in the bellows pump 103 can be conveyed ashore.

A valve system 119 is associated with the inlet 109 and the outlet 111. The valve system 119 includes an inlet valve 121 adapted to open upon volume expansion of the pumping chamber 101 and adapted to close upon volume reduction of the pumping chamber 101. In this embodiment, the inlet valve 121 is in the form of a flap valve. The valve system 119 further includes an outlet valve 123 associated with the outlet 111. The outlet valve 123 is adapted to close upon volume expansion of the pumping chamber 101 and to open during volume reduction, but only after seawater contained within the pumping chamber 101 attains a prescribed pressure. In this way, water is discharged from the pumping chamber 101 is at a higher pressure than the intake pressure. In this embodiment, the outlet valve is in the form of a spring-loaded valve.

Operation of the apparatus 10 can be seen with reference to Figures 1 and 2. In the drawings, the mean wave position is depicted by a line identified by reference numeral 150, with wave peaks being identified by reference numeral 151 and wave troughs by reference numerals 152. The passage of a wave peak 151, as depicted in Figure 2, causes the plunger 31 to deflect downwards in response to

the water above. After the passage of a wave peak 151, the situation of Figure 1 applies and the plunger 31 returns to its fully raised position, which is approximately level with the upper surface of the apparatus 10.

The holding chamber 51 is not closed to the seawater. This is an important aspect as it removes the need for a water seal between the upper and lower portions 41, 43.

The level 61 of seawater 60 within the holding chamber 51 is set in part by the pressure of the air above it. In normal operation, the level of the seawater will vary slightly in accordance with the pressure of the air but will be always below the upper edge of the inner wall portion 23. The seawater contained in the holding chamber 51 serves to isolate the seawater surrounding the apparatus 10 from the air contained in zone 73. The holding chamber 51 also provides the feed for the bellows pump 103 via a feed line 113 located at the bottom of the holding chamber 51 and connecting to the low-pressure inlet 109 of the manifold 107. Seawater is drawn up into the pump 103 via the feed line 113 and is replaced by seawater entering from the outside via the gap 47.

A means of reverse flushing the filter at the intake end of the feed line 113 during maintenance periods may be provided by way of extra piping and valves (not shown). The filter may also assist in providing ballast to the apparatus 10.

The hydraulic motor 83 and 91 for driving the air pump 81 and water pump 85 respectively are driven by high-pressure seawater via a takeoff feeder 131 from the high-pressure line 117.

Alternatively the hydraulic motor and pump may be comprised of a pair of positive displacement pumps using elastomer bellows similar to the ones employed for the seawater pressurization. In this case one elastomer bellows would be configured as the motor and the other configured as a pump.

The air pump 81 maintains the air pressure in the zone 73 at a set point wherein the pressure is sufficient to support the weight of the plunger 31 and attachments thereto such that the plunger 31 remains level with the top of the apparatus during a wave trough 152, as shown in Figure 1. The control of airflow is straightforward given that any air in excess of this pressure will automatically escape from under the plunger 31 via the gap 47and bubble to the surface.

The air pump 81 may also be made reversible so that it can reduce the pressure within the zone 73. This feature may be employed when it is desired to lower the plunger 31 during storm conditions, or for routine maintenance.

The air in the zone 73, together with the mass of the plunger 31 and attached hardware, constitute an air spring system with a characteristic resonant period. The elastic compliance of the elastomer bellows pump 103 may also contribute to the spring constant of the mechanical system and thus modify the resonant period. The apparatus 10 is sized so that this natural resonant period falls within the range of periods of ocean waves having the dominant energy. Typically, this period ranges between four and 12 seconds. Preferably the range of periods is narrower, from six to ten seconds. Preferably it desired to tune the resonant period to the period of the dominant waves. The damping imposed by the energy extraction, nonetheless broadens the response of the system so that it effectively responds to a range of wave periods.

With reference to Figure 1, the plunger 31 is momentarily at rest during the passage of a wave trough 152. The plunger 31 is at its fully raised position and the bellow pump 103 is momentarily stationary. The bellows pump 103 in maximum extension has drawn up a charge of filtered seawater from the low pressure feed line. Seawater flows into the holding chamber 51 via the gap 47 around the plunger 31 to restore the water level. With reference to Figure 4, the airflow pattern is such as to equalize the pressure by air flowing from the auxiliary chamber 53 back into the upper region of the holding chamber 51.

With reference to Figure 2, the plunger 31 is momentarily at rest at its maximally depressed position during the overhead passage of a wave peak 151. The bellows pump 103 is now fully compressed and has delivered its charge of pressurized seawater to the high-pressure line 117 via a one-way valve 123 in the manifold 107.

The extent of pressurization that can be reached within the elastomer bellows pump 103 is determined primarily by the ratio of areas of the plunger 31 to the contact area of the bellows onto the plunger.

It is an aspect of this embodiment that positive displacement pumps, made of elastomer and disposed as bellows, are capable of providing pressures in excess of 70 atmospheres. Any alternative displacement pumps with appropriate pressure and stroke ratings may be substituted in this role without altering the scope of the invention.

This embodiment utilizes a single-ended pumping arrangement in that pressurization of seawater within the single bellows pump 103 occurs only on the downward stroke of the plunger 31. The upward stroke merely expands the bellows and causes the flap valve 121 in the manifold 107 to open to the low pressure feed line 113 and allow the bellows to fill with a fresh charge of seawater under the action of suction. During compression, the flap valve 121 in the manifold 107 closes on the low-pressure line 113 exposing the bellows charge to the high-pressure line 117. The one-way valve 123 will open when the pressure of this water reaches a preset threshold admitting high-pressure water to the line.

The first embodiment utilizes a single bellows pump 103 mounted on the support frame 105. The stroke of the single bellows pump may be made larger than the stoke of individual bellows in the later embodiments and this offsets the inherent disadvantage of employing a single-ended pumping scheme *vis a vis* a push-pull arrangement as in the later embodiments.

Apparatus according to a second embodiment of the invention is shown in Figures 14 to 19. This embodiment employs a push-pull pumping arrangement wherein seawater is pressurized on both the upward and the downward stroke of the plunger 31. This is achieved with two bellows pumps 103a, 103b working in opposition. The pumps are disposed axially one above the other with a dual manifold 161 interconnecting the two bellows. The dual manifold 161 contains within one housing two sets of one-way valves 123 and flap valves 121 that are each identical to the elements in the manifold 107 of the first embodiment. The dual manifold 161 is rigidly attached to a rigid support frame 163 that is attached to the base 13 of the apparatus. A rigid connecting strut 151 attaches at one end to the base of the lower bellows 103a and communicates force to the plunger 31 where the other end is rigidly attached. The upper bellows 103b is rigidly attached to the underside of the plunger 31 while its other end is rigidly attached to the support frame 163. Downward motion of the plunger 31 causes the upper bellows 103b to contract producing pressurized seawater while the lower bellows 103a expands and draws in seawater. On the upward stroke the situation is reversed.

Apparatus according to a third embodiment of the invention is shown in Figures 20 to 22. This embodiment employs the same manifold and same type of valve arrangement as the first embodiment but uses a push-pull pumping scheme using two bellows 103a, 103b similar to the second embodiment. The difference between the second and third embodiments is in the manner in which the bellows 103a, 103b are stretched. In the third embodiment, the outer ends of the bellows 103a, 103b are fixed and provide the connection to the manifold for fluid feed and take off. The centre connection between the two bellows is rigidly connected to a frame 171 that is then rigidly connected to the plunger 31. In this way the central connection between the bellows 103a, 103b moves with the plunger 31 while the ends of the bellows remain fixed. This is the opposite of the second embodiment wherein the central portion and dual manifold remain fixed but the ends of the bellows move. The second embodiment utilizes a more complex manifold than either the first or third embodiment whereas the third embodiment requires extra piping to connect to the two sets of manifolds.

It is apparent that the second and third embodiments provide power strokes on both the upward and downward motions of the plunger 31 but with a displacement per bellows that is less than that provided by the single ended bellows arrangement of the first embodiment. The second and third embodiments provides a somewhat smoother production of pressurized seawater than the single.

It should be understood that the scope of the invention is not limited to the scope of the embodiments described. For example, while the embodiments have been described with reference to a body structure of cylindrical construction, it should be understood that other configurations are possible. A rectangular configuration may, for instance, provide benefits in certain applications in that a wall thereof can be disposed so as to be generally parallel to approaching wave fronts.

Modifications and improvements can be made without departing from the scope of the invention.

Throughout the specification, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

Dated this twenty third day of December 2002.

Seapower Pty Ltd
Applicant

Wray & Associates
Perth, Western Australia
Patent Attorneys for the Applicant

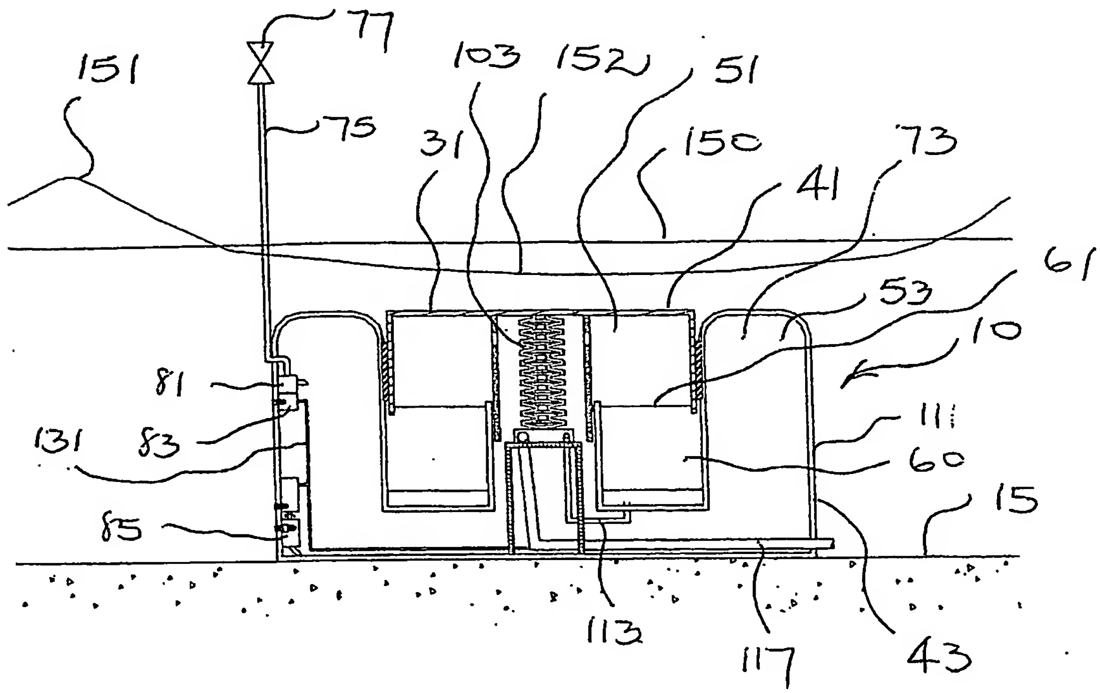

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Figure 1

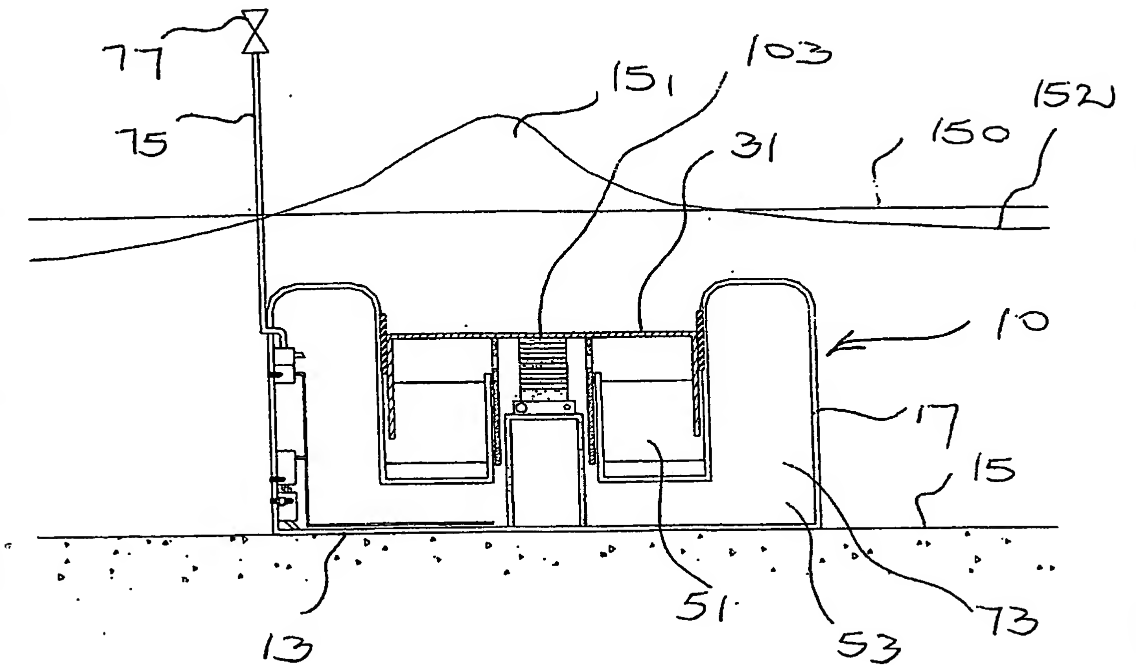
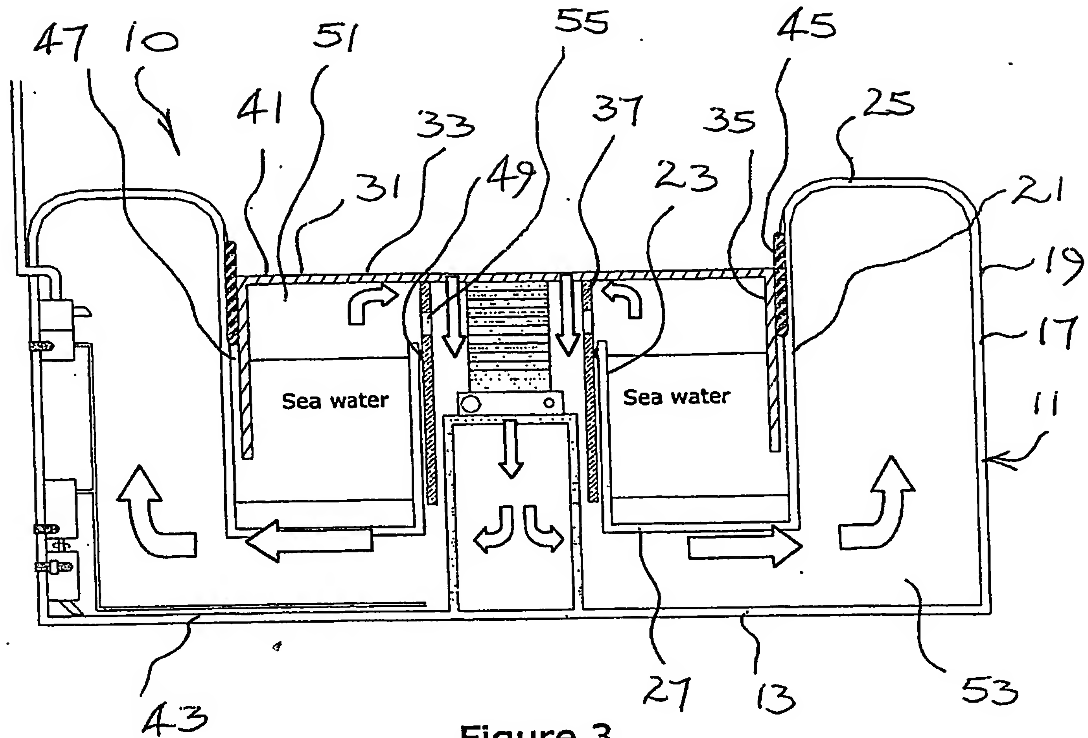


Figure 2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10
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55
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13
53

Figure 3

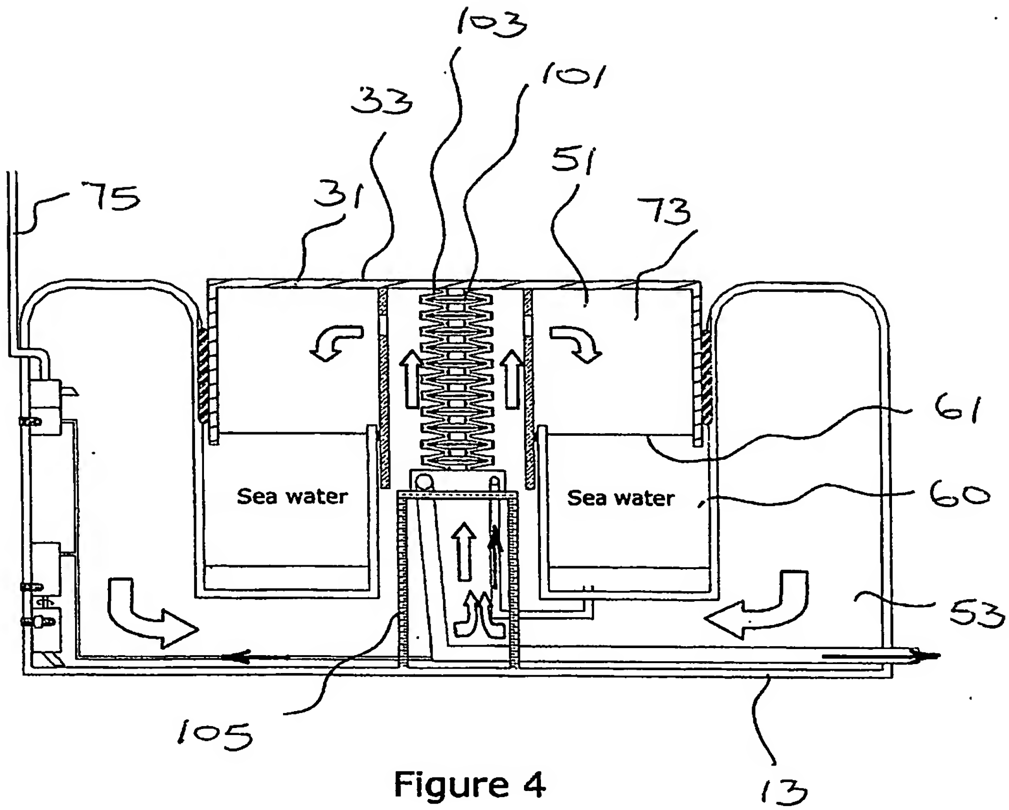


Figure 4

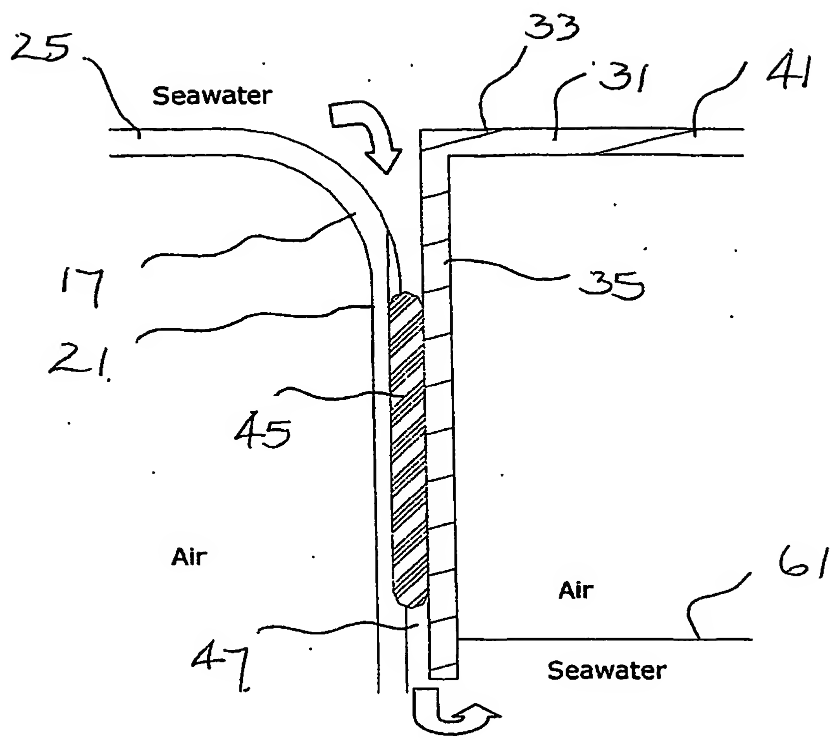


Figure 5

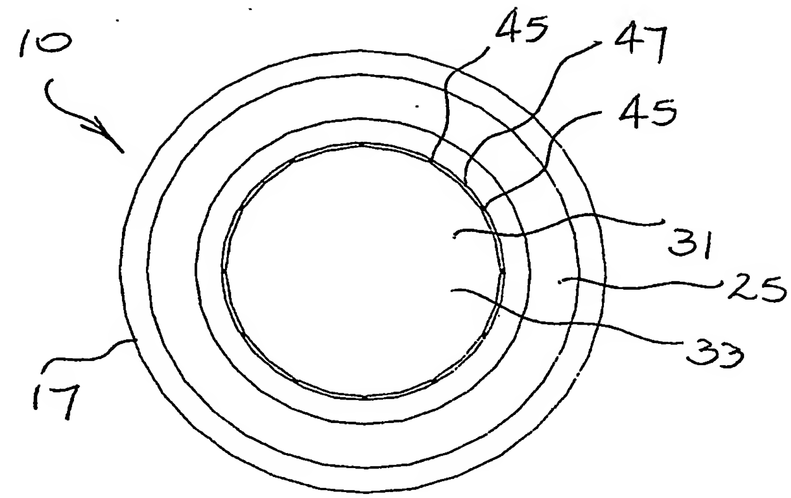


Figure 6

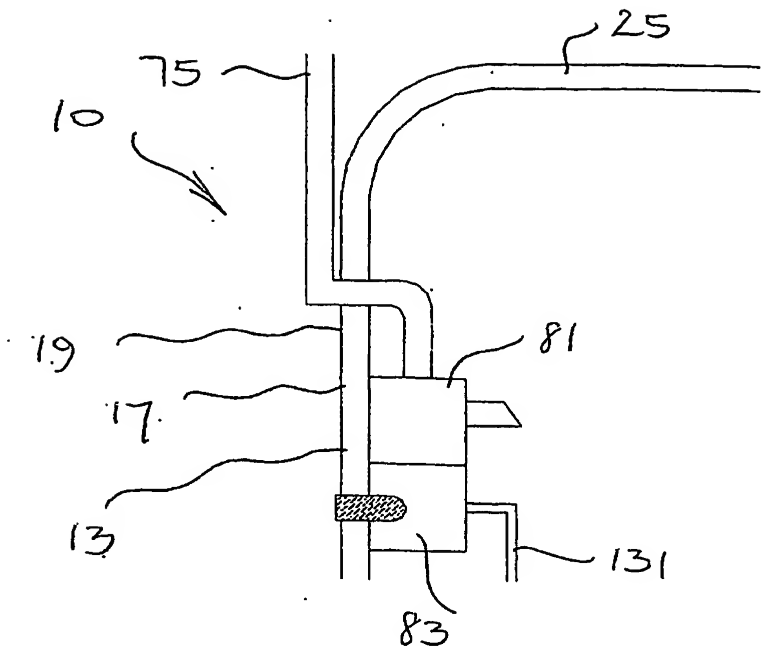


Figure 7

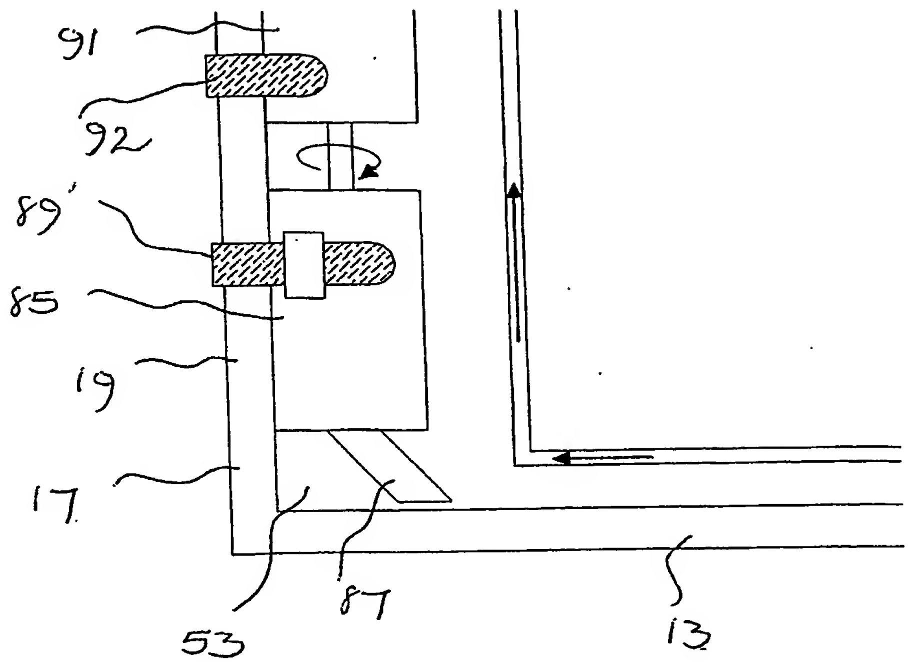
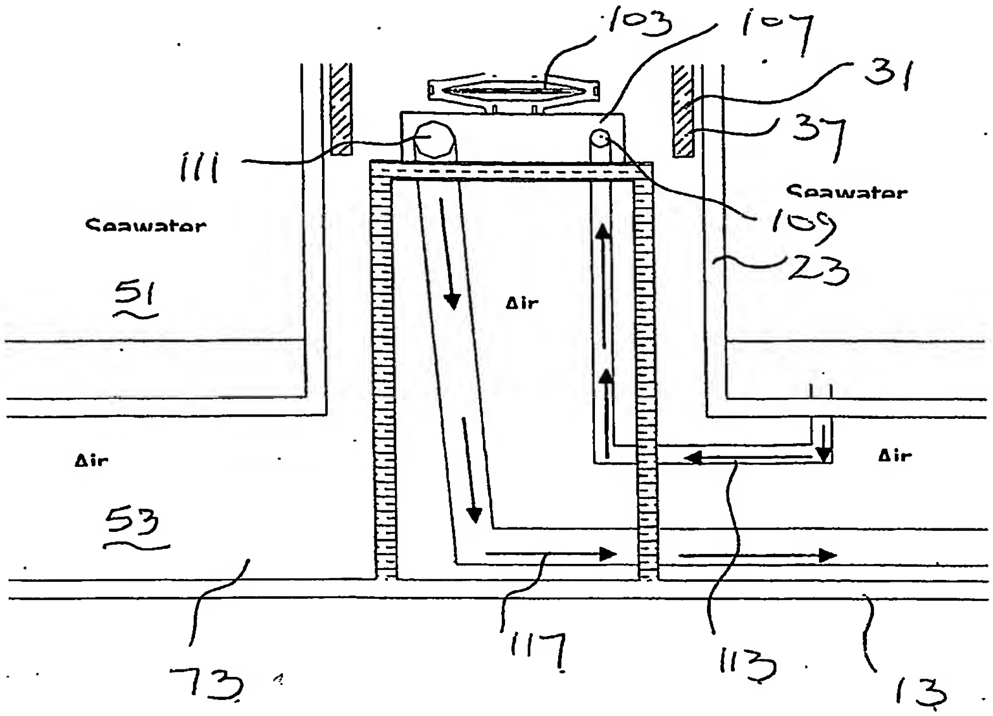


Figure 8



103
107
31
37
111
Seawater
Seawater
109
23
51
Air
Air
Air
53
117
113
73
13

Figure 9

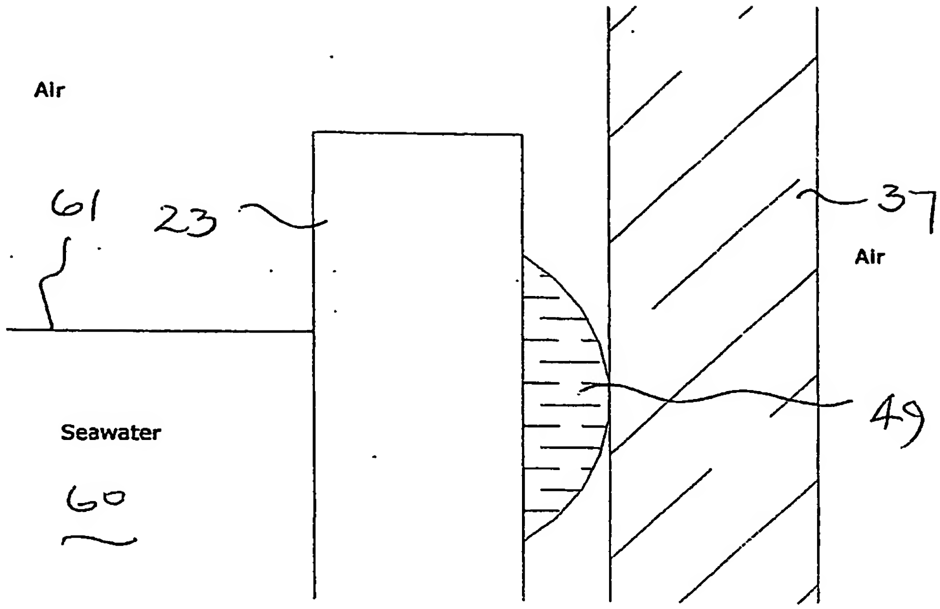


Figure 10

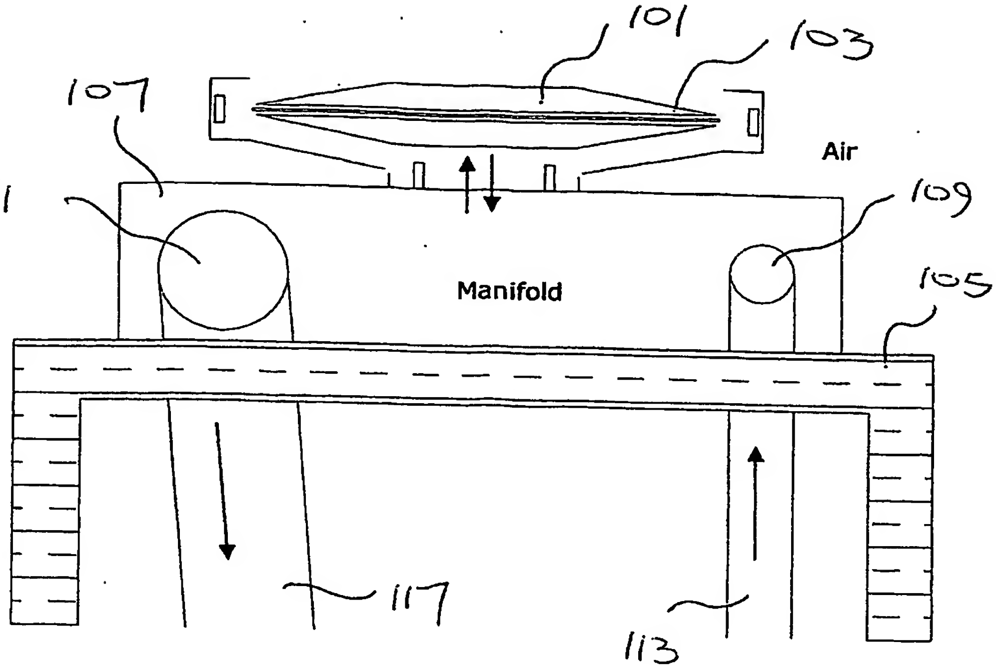


Figure 11

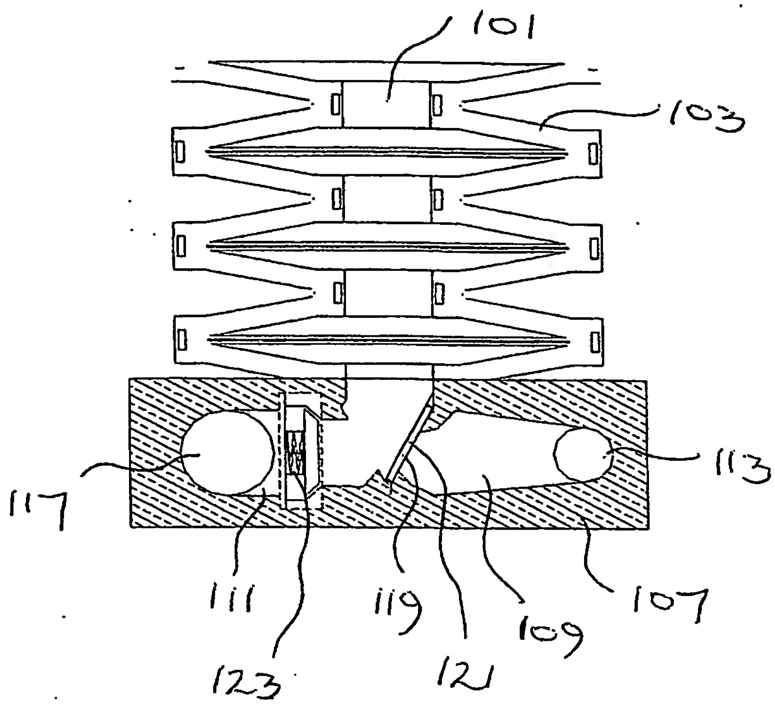


Figure 12

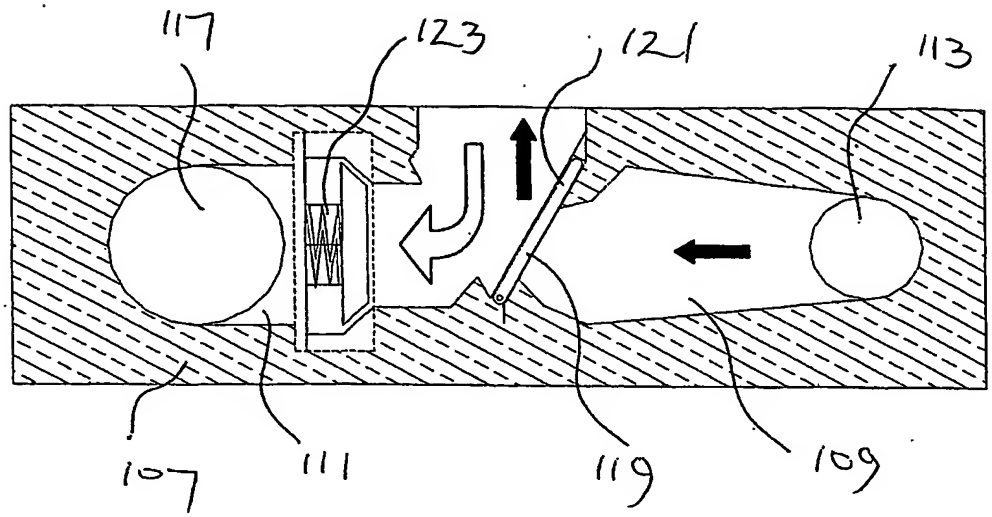


Figure 13

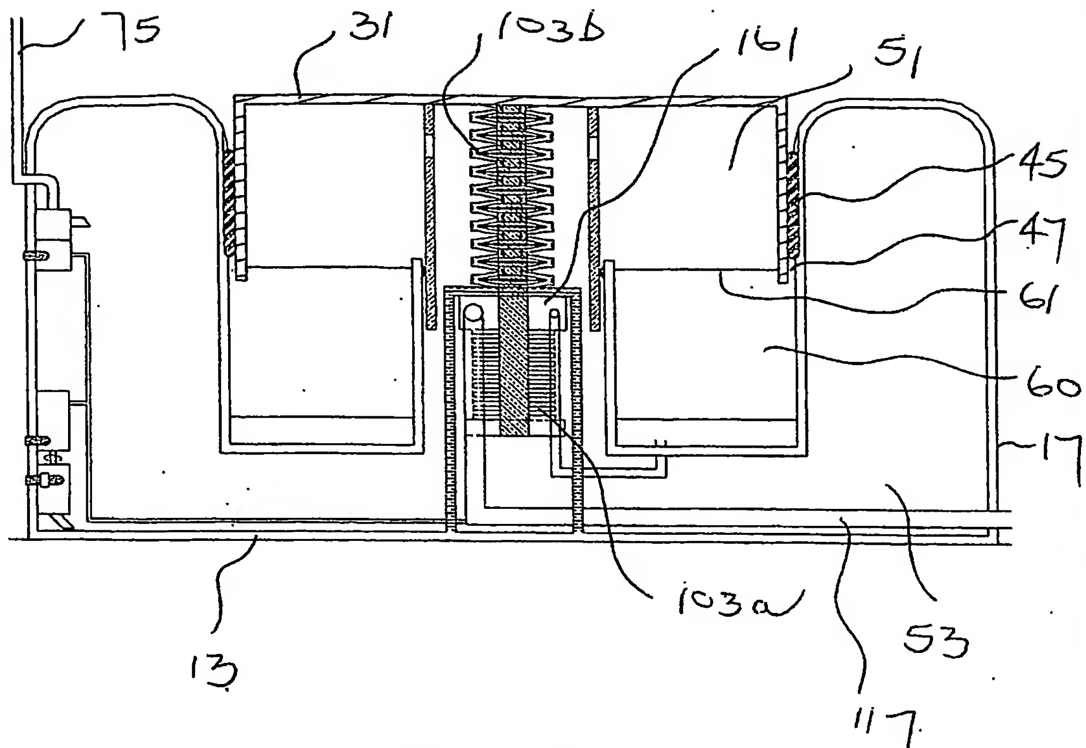


Figure 14

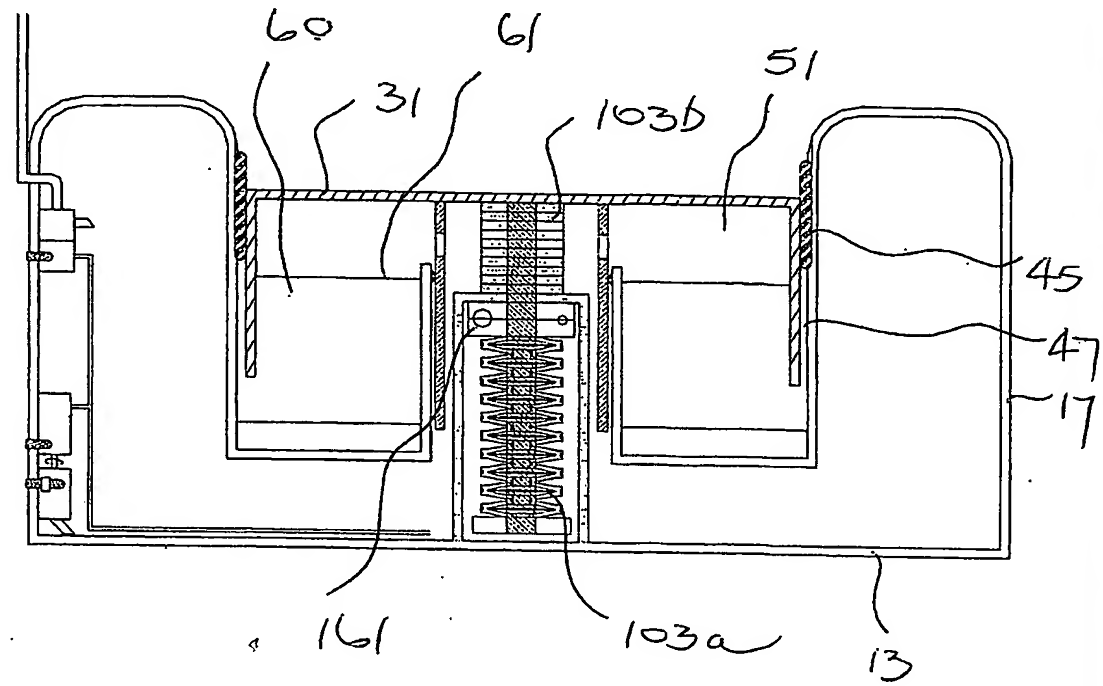


Figure 15

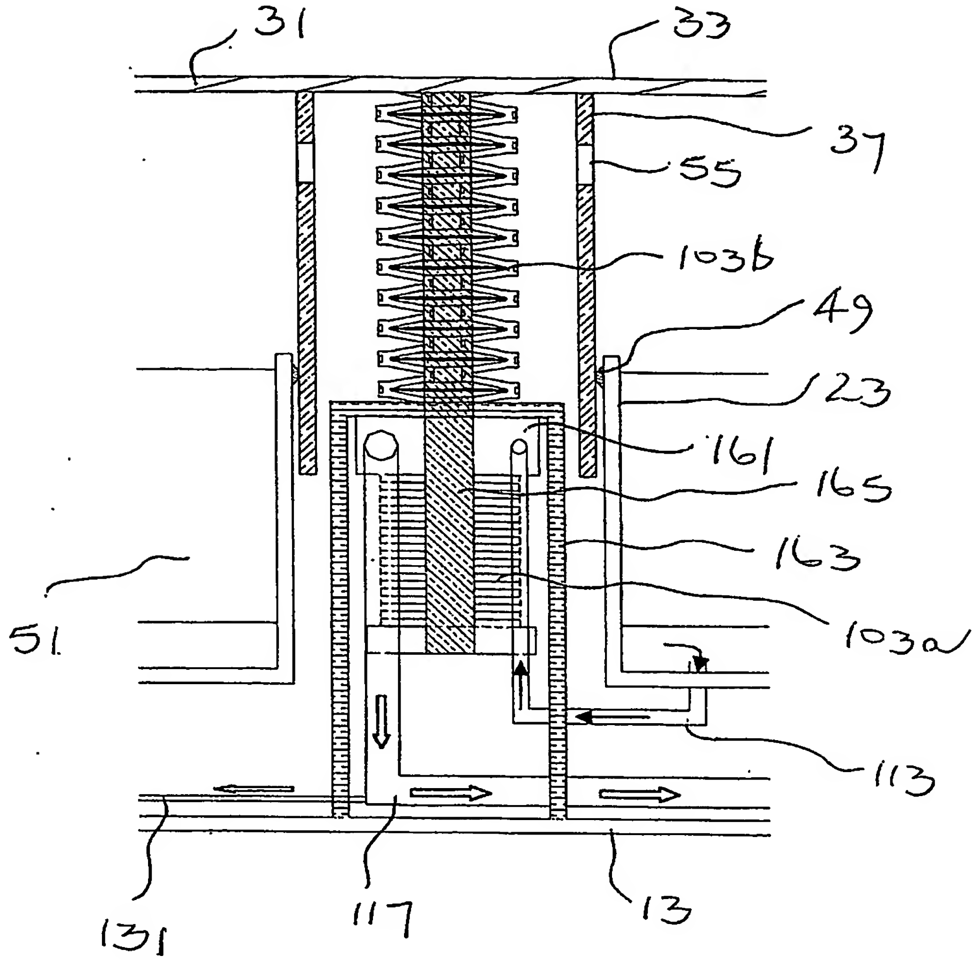


Figure 16

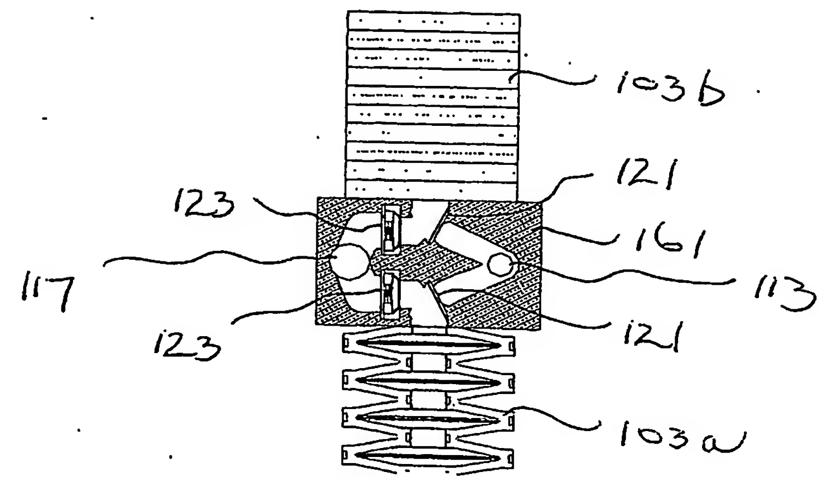


Figure 17

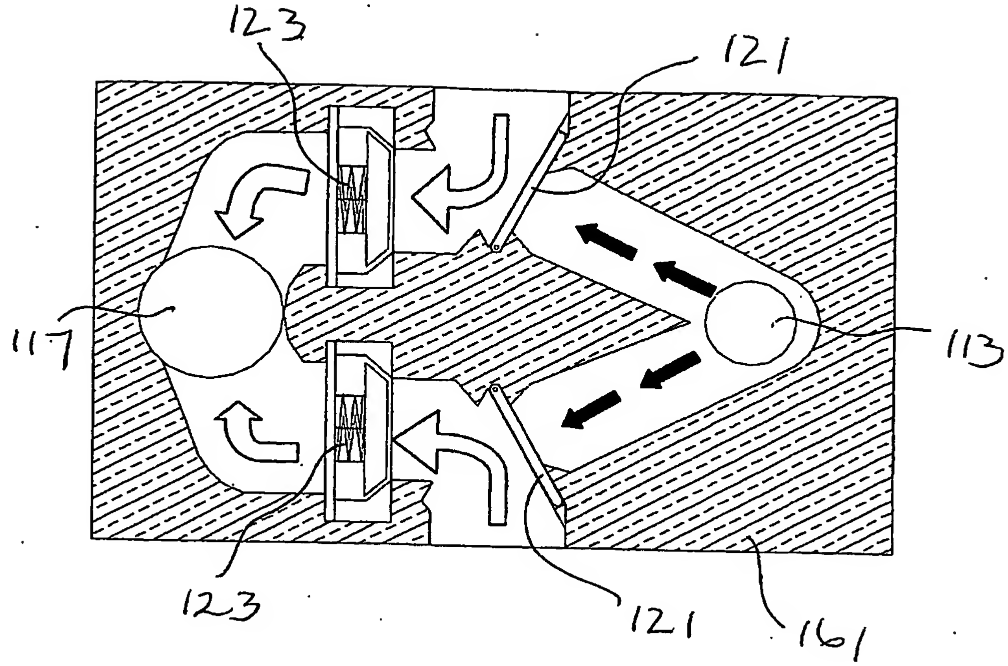


Figure 18

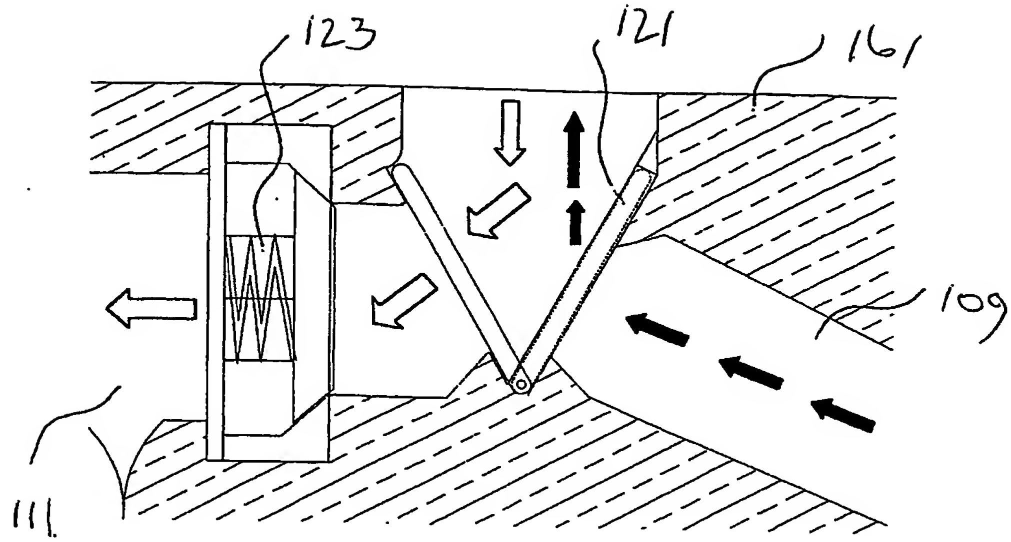


Figure 19

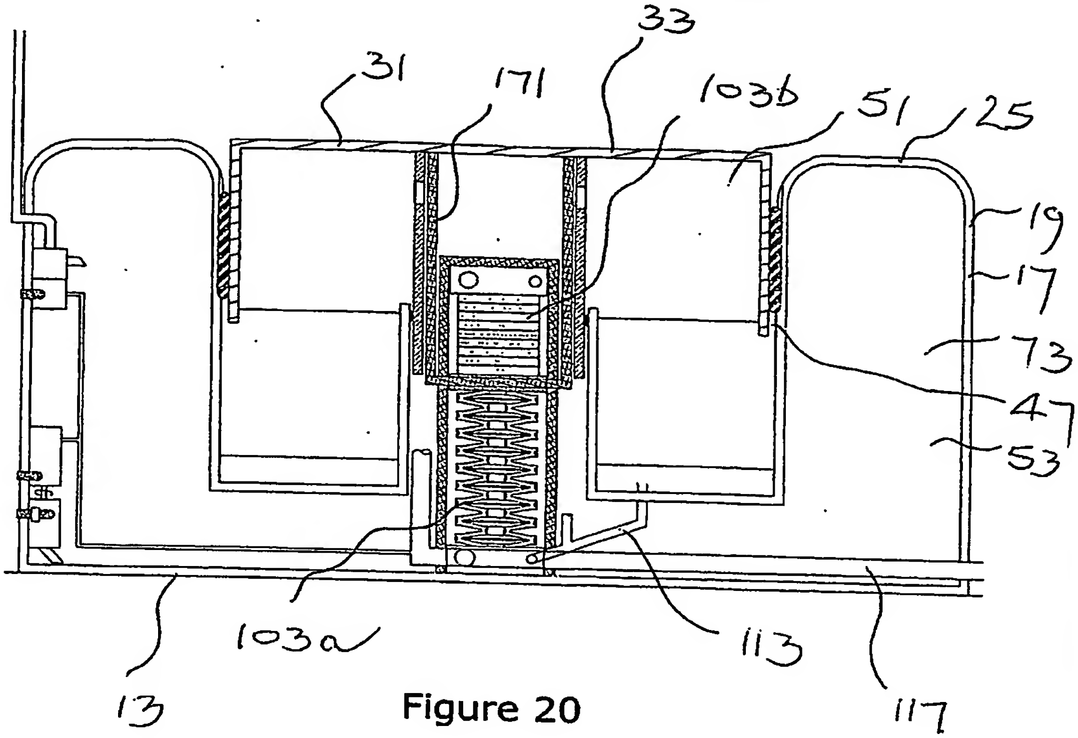


Figure 20

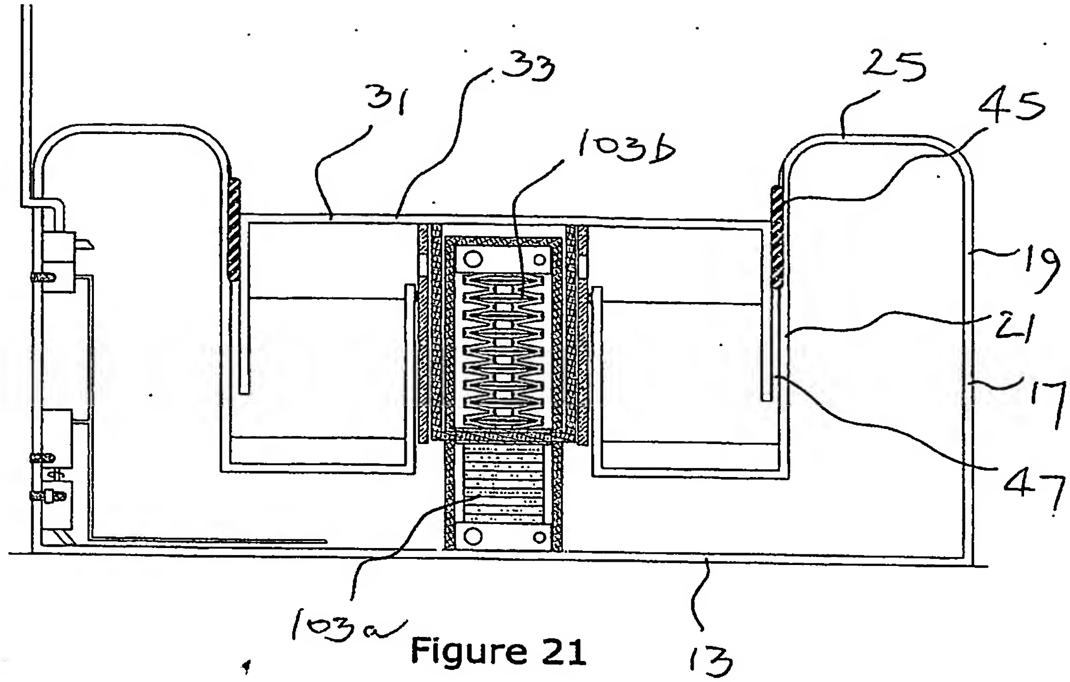


Figure 21

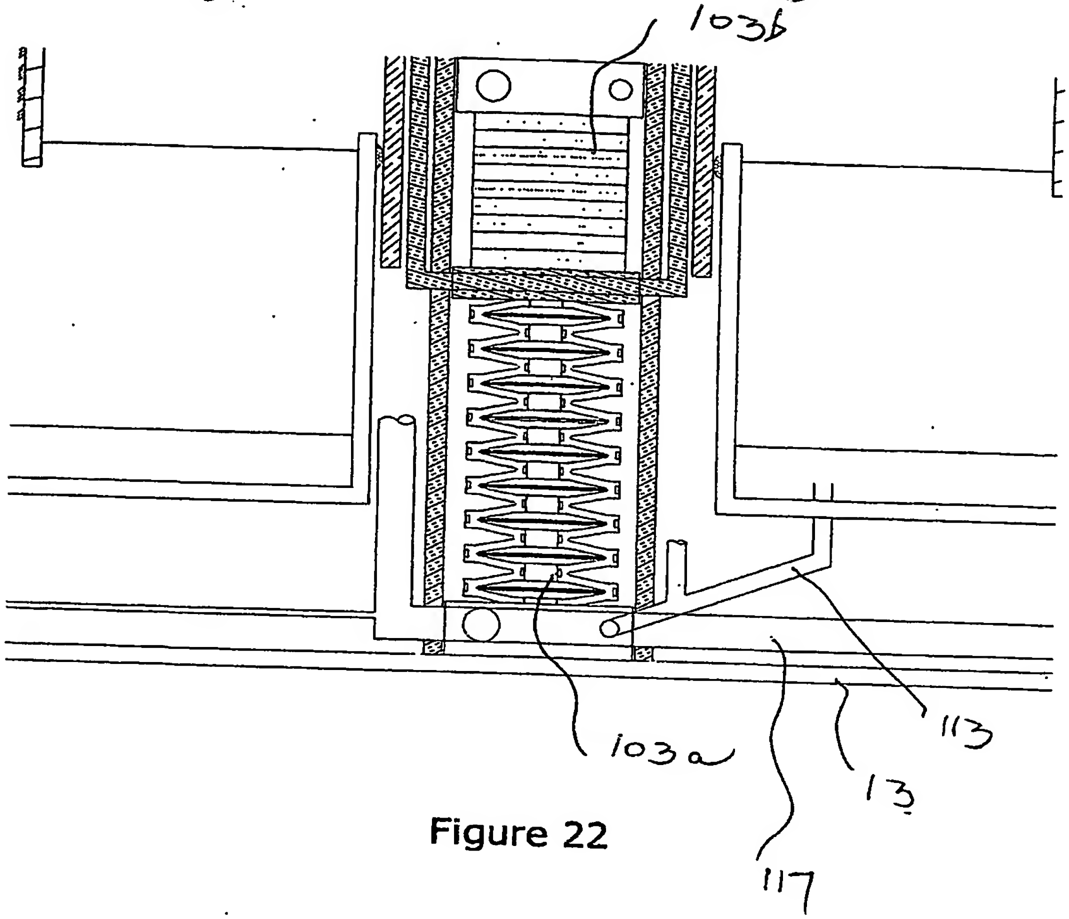


Figure 22